Environment Agency - Abu Dhabi (EAD)

MARINE HABITAT CLASSIFICATION

Document Status

Version	Date	Pages	Comments

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1. Introduction

1.1. Purpose

The purpose of this document is to provide a detailed description of each marine habitat types and subtypes. The principal outcome of the marine part of the project is a habitat, sea-floor cover, and benthic map of Abu Dhabi Emirate waters derived from multiple sources of multispectral satellite imagery.

1.2. Scope

The Abu Dhabi Environment Agency (EAD) was formed in 1996 with the intention of promoting sustainability and raising environmental awareness within the Abu Dhabi Emirate. Accurate and up to date understanding of the current ecological situation is crucial to inform of change and to plan for the future.

A principle aim of this project is to provide a habitat, sea-floor cover and benthic map for the Abu Dhabi Emirate marine areas using satellite derived imagery.

This document defines the marine nomenclature schema that will be used for classification.

1.3. Structure of the document

The document provides details of the following topics:

- Definitions and explanations of the terms and concepts used.
- Overview of the marine ecotypes present in Abu Dhabi waters.
- Specific descriptions of each nomenclature category.

1.5. Acronyms and Terms

Acronym \ Term	Meaning \ Definition
A priori	An *a priori* classification system is based upon the definition of classes before data collection takes place.
Benthic	Benthic refers to anything associated with or occurring on the bottom of a body of water[3].
Classification	Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers. A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes. Classification thus necessarily involves definition of class boundaries that should be clear, precise, possibly quantitative, and based upon objective criteria. A classification should be scale independent and source independent[1].
EAD	Environment Agency Abu Dhabi
Habitat	An ecological or environmental area that is inhabited by a particular species of animal, plant, or other type of organism. It is the natural environment in which an organism lives, or the physical environment that surrounds (influences and is utilized by) a species population[4].
Legend	A legend is the application of a classification in a specific area using a defined mapping scale and specific data set. A legend is scale and cartographic representation dependent, and data and mapping methodology dependent[5].
LS	LandSat multispectral satellite imagery.
RE	RapidEye multispectral satellite imagery.
WV-2	Digital Globe WorldView 2 satellite imagery.

2. Background to the Classification Process

The *a priori* classification schema that will be used within the marine section of the project is based on CMRECS classification schema. This is a derivative of the US federal Geographic Data Committee's Coastal and Marine Ecological Classification Standard (CMECS).

However, the CMRECS guide has been refined here to consider what is possible with satellite image interpretation. In the purest sense of the definition the schema used within this project is therefore a "legend" as it is the application of a classification in a specific area using a defined mapping scale and specific data set[1] (i.e. using multi-spectral satellite imagery of Abu Dhabi Emirate).

A detailed description of the characteristics of each classification category is provided within section 5 of this document, and includes discussion of the limitations of satellite sea floor classification. For the purpose of completeness, a background to the Ecotypes found within Abu Dhabi waters is provided in section 4.

2.1. Principles of Abstracting Reality

Classification of a specific location is dependent on the spectral signal of each individual pixel. For example, if both seagrass and macroalgae are present (at densities which comply with the habitat definition), the component with the dominant signature takes precedence (i.e. that component with the greatest presence). If one of these biotic components is present and the habitat classification criteria are met, then the area is assigned to that habitat type. Areas that are comprised of both hard-bottom and unconsolidated substrates will be classified according to the dominant spectral signature, although it must be noted that the classification is based on the surface of the area, and even a very thin veil of sediment will return an unconsolidated signature.

Similarly (although to a lesser degree), other habitats are usually not homogenous. Coral reef habitats routinely contain patches of hard-bottom and unconsolidated substrates, seagrass beds will contain 'blow-outs' of exposed sand. However, in all cases, each pixel has been classified by its dominant habitat type.

2.1.1. Minimum Mapping Unit

Unlike the terrestrial part of this project, Minimum Mapping Units (MMUs) will not be applied within marine interpretation. The largest pixel size (5m x 5m RapidEye imagery) provides the Minimum Mapping Unit of all habitats. EAD have confirmed that the level of detail provided by a pixel-by-pixel interpretation is acceptable.

2.1.2. Coverage of classification

The marine classification will work wherever there is permanent sea water cover, and will depict each point on the sea floor to a unique habitat category. The habitat categories have therefore been defined to ensure that they encompass all habitat types evident within Abu Dhabi waters. It must be noted that inter-tidal habitats are portrayed within the terrestrial map and described within the terrestrial habitat dossier.

2.2. Project-wide categorization rules

CMRECS modifiers will be used to aid differentiation between habitats. This provides a biological justification to each of the depicted habitat categories.

2.2.1. CMRECS Density Modifier

The CMRECS modifier for live cover will be used to classify habitats with live flora (table below).

Seagrass bed (12000) and Macro algae (11110, 11210, 13010) will be identified where plant cover is Moderate or Dense.

Where plant cover is sparse, seagrass and algal plants cannot be differentiated. Therefore the sea floor will be classified according to the underlying substrate (e.g. unconsolidated bottom (14000) or Hardbottom (13000)).

CMRECS "Other" Modifier	Definition
Dense Cover	>75% live cover
Moderate Cover	25% - 75% live cover
Sparse Cover	<25% live cover

2.2.2. CMRECS Substrate Modifier

The CMRECS modifier for particle size will be used to differentiate between hard bottom and unconsolidated bottom (table below). The measurement units are taken from the Wentworth scale.

Where particle size is "pebble" or larger, the sea floor will be classified as hard bottom. Where particle size is "gravel" or smaller, the sea floor will be classified as unconsolidated bottom.

CMRECS "Substrate" Modifier	Definition
Bedrock	Substrate composed of attached bedrock
Boulder	Substrate composed of boulders (>256mm)
Cobble	Substrate composed of cobbles (256-64mm)
Pebble	Substrate composed of pebbles (64mm-4mm)
Gravel	Substrate composed of gravel (4-2mm)
Sand	Substrate composed of sand (2-125 μm)

Mud	Substrate composed of silt and clays (<125 □m)

3. List of the classification types to be used

3.1. Overview of habitat categories with map colours

Type no.	Sub-type no.		Habitat type	Map Legend
11,000			Coral reef	*Not Mapped*
	11,100		Fringing reef	
		11,110	Fringing reef with macroalgae	
	11,200		Patch reef	
		11,210	Patch reef with macroalgae	
12,000			Seagrass bed	
13,000			Hard-bottom	
		13,010	Hard-bottom with macroalgae	
14,000			Unconsolidated bottom	
15,000			Marine construction	*Not Mapped*
	15,100		Rock armouring / artificial reef	
	15,200		Marine structure	
16,000			Dredged areas	*Not Mapped*
	16,100		Dredged seabed	
	16,200		Dredged area wall	
17,000			Deep sub-tidal seabed	

3.2. Detailed habitat categories with definitions

Type no.	Sub-type no.		Habitat type	Definition	Depth limit for classification*
11,000			Coral reef	High relief subtidal feature formed largely of coral rock	
	11,100		Fringing reef	Linear coral reef structure close to and parallel to the shoreline	7-8m
		11,110	Fringing reef with macroalgae	Fringing reef structure with greater than 25% macroalgae cover	10m
	11,200		Patch reef	Isolated, coral outcrop (s) with no distinct axis relative to the shore	7-8m
		11,210	Patch reef with macroalgae	Patch reef structure with greater than 25% macroalgae cover	10m
12,000			Seagrass bed	Subtidal habitats with a minimum of 25% cover seagrass	10m
13,000			Hard-bottom	Solid substrate (75% cover of rock or sediment classed as 'gravel' or larger) without significant live or dead coral colonisation	10m
		13,010	Hard-bottom with macroalgae	Hard-bottom habitat where macroalgae cover is greater than 25%	10m
14,000			Unconsolidated bottom	Greater than 25% cover of sediment smaller than 'gravel' and without significant coral, seagrass or algal colonisation	12-15m
15,000			Marine construction	Artificial structure which is entirely or partially subtidal	*Not mapped*
	15,100		Rock armouring / artificial reef	Modular structure built with uncemented rock or concrete units	2-3m
	15,200		Marine structure	Man-made structures (other than rock armouring) including jetties, oil platforms, bridges, aquaculture infrastructure, etc.	*Super-tidal*
16,000			Dredged areas	Areas where the depth has been increased by artificial means	*Not mapped*
	16,100		Dredged seabed	Dredged areas where the seabed gradient is less than 35°	10-12m
	16,200		Dredged area wall	Boundary of a dredged area with a gradient greater than 35°	*Line feature*
17,000			Deep sub-tidal seabed	Areas that are too deep to be mapped using satellite imagery.	*Unlimited*

* **Note**: All classification depths depicted within the dossier are based upon imagery that is free of sunglint and turbidity. Where sunglint and turbidity exists within satellite imagery, the depth limits may be reduced.

4. Eco-types

While each location may support its own unique mix of species, basic community types may be broadly described, grouped and classified based on their fundamental or dominant organisms. These groups, termed ‘Ecotypes’, are defined in the CMRECS documentation as the ‘...associated biological community of each [habitat]’.

In this document, biological communities in Abu Dhabi have been divided into four broad biotic ecotypes:

- Corals
- Seagrass
- Macroalgae
- Fouling communities

The first three ecotypes are in line with the CMRECS system (‘macroalgae’ here being analogous to the ‘algal bed’ class in CMRECS), with an additional fourth category of ‘fouling community’ added due to the extensive areas of coastal development and the numerous marine structures in the Emirate. A fifth ecotype of ‘bare’ is included in the CMRECS system, which may be applied to habitats with a low level of colonisation. From CMRECS documentation this is inferred as being less than 25% cover of seagrass, macroalgae or coral, with fouling community added to this list by extension.

In many cases, an ecotype may be present in two or more distinct habitats. Rather than replicate basic descriptions for each habitat, the purpose of this section of the document is to describe the fundamental components of each ecotype. Detailed background information is also provided to supplement the descriptions of each habitat in section 5.

In addition, to fully understand the distribution of marine habitats across Abu Dhabi, it is advantageous to have a broader overview of the biological components associated with each habitat type. This is particularly useful for the following reasons:

- Appreciation of habitats which are currently in a state of flux and / or decline (especially coral reefs).
- Providing an understanding of temporal and spatial changes inherent in dynamic systems.
- Understanding the implications mixed ecotypes over a small spatial scale (Section 4.5).

4.1. Corals

Scleractinian (hard) corals are the foundation of coral reefs (sections 5.1). They also occur extensively in non-reef settings; forming coral communities on hard-bottom habitats (where no permanent reef structure is left), and they are frequently present on structures such as rock armoured breakwaters. These corals are vitally important for their highly biodiversity, not just locally but throughout the Gulf. Having survived temperature ranges greater than anywhere else in the world, their physiological and ecological adaptions to such conditions and the limits to which they can be pushed provide crucial information on a global scale as sea temperatures are set to rise further worldwide.

With the extreme heat experienced in the Gulf during the summer, coral bleaching has been, and still is, a common occurrence, and coral colonies often show full recovery following such events. However, climate change has resulted in a series of elevated summer sea temperatures, most notably during 1996, 1998, 2002 and 2010. Following these anomalies, widespread coral mortality has been recorded, including, for example, an estimated 95% of branching corals following the 1996 event and 80% of massive corals after the 1998 event. While some recovery follows such events, as a consequence of these mass mortalities, coral communities in the Gulf have changed considerably over the course of the last two decades.

The coral rock of which reefs are composed is principally formed from the carbonate skeletons of scleractinian corals. These corals (to a greater or lesser extent), have been cemented together with sediments and other biogenic matter by various physical and biological processes (coralline algae often plays a significant role) to form a solid substrate which other corals may colonise. While this process requires living corals for continued formation and growth of reefs, following a series of elevated summer sea temperatures resulting in broad-scale coral mortality, not all coral reefs still currently support living corals (see below). In such cases the reef structure will remain (though it will be eroded over time) and an alternate, usually algal-dominated community may colonise the reef.

Coral reefs (especially 'live coral' reefs) are renowned for their biological wealth and may support a diverse array of associated species, which usually includes an abundant fish community. Following coral mortality, the structural complexity of the reef is usually preserved in the short term, and algal-dominated reefs may perform some, though not all, of the ecosystem functions provided by 'live coral' reefs. For example they often support similar abundances and diversities of fish, though not necessarily the same species. However, reefs with minimal live coral cover are no longer self-sustaining and become increasingly more eroded over successive years, losing the structural complexity essential to much of the associated community. This is especially true of the acroporid or branching corals, which are more fragile and broken down more quickly. Although such changes take several years to take effect, with the 1996 temperature anomaly now 18 years ago (at the time of writing) these effects are well and truly apparent. Extensive areas which functioned as coral reefs a few years ago, have been eroded to such an extent that they no longer provide the same ecosystem functions and they are fast approaching a point where they no longer qualify as having the 'high relief' required to classify them as coral reefs.

Selected bibliography describing the effects of the 1996, 1998 and subsequent temperature anomaly on coral reefs in the UAE:

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4.2. Seagrass

Seagrasses are flowering plants (angiosperms) which have uniquely adapted to a fully marine lifecycle. Three species occur in the gulf; Halodule uninervis, Halophila stipulacea and Halophila ovalis. All three are widespread in Abu Dhabi coastal, near-shore waters.

Halodule uninervis is the most abundant species in the Gulf (Basson 1977, Price and Coles 1992), and often forms dense, lush meadows either mono-specifically (especially in the shallow sub-tidal / lower intertidal zones, where it can even survive occasional periods of exposure) or in combination with the other species. It is also a pioneer species and likely to be the first of the three species to colonise new habitats. Halophila stipulacea generally shows a relative increase at mid depths (4 to 10m), and often forms dense mixed meadows with comparable proportions of Halodule uninervis and lower densities of Halophila ovalis. Maximum shoot density for Halophila ovalis tends to be lower than for the other two species. It is a hardy species and often thrives in conditions of greater depths and turbidities, where the other two species have difficulty growing. It has occasionally been recorded at over 20m depths in the Gulf (NEA records) although it is also usually present in shallower, mixed seagrass beds.

Seagrass beds are a 'critical habitat', playing a vital role in the life cycle of many commercially important fisheries species, as well as being the primary food of Green Turtles and Dugongs.

4.3. Macroalgae

'Macroalgae' is a broad, functional classification, with no clear consensus as an exact definition, although may generally be regarded as simple (i.e. lacking distinct cell organelles), multi-cellular marine plants that are visible to the naked eye.

They may be divided into three major groups: brown algae (Phaeophyceae), green algae (Chlorophyta) and red algae (Rhodophyta). These three groups are of differing taxonomic ranks and are not thought to have a common ancestor (i.e. 'macroalgae' is polyphyletic). Although all contain chlorophyll, their eponymous colouration is due largely to the presence of different photosynthetic pigments which absorb light energy across distinct parts of the spectrum. The wavelengths that brown and green algal pigments absorb are do not penetrate the water column as far as those of the red algae, restricting the former to shallower waters, while in the Gulf the latter may sometimes be found at depths of over 20m.

In Abu Dhabi, macroalgal communities generally require a hard substrate on which to adhere. As such, they are closely associated with hard-bottom habitats, although analogous communities are present on other solid surfaces such as reefs (where live coral cover is limited), rock armoured breakwaters and marine structures.

There are a number of distinct components of macroalgal communities which may or may not be mixed in varying proportions depending on conditions such as season, substrate, depth and wave exposure. These include:

- Seasonal Sargassaceae (large brown algae)
- Epilithic macroalgae
- Coralline (red) algae
- Turf algae

Seasonal sargassaceae often dominate in shallow water, forming luxuriant stands which can tower up to 1m above the substrate from around November to April. Seasonal Sargassaceae such as Sirophysalis trinodis (formerly Cystoseira trinodis), Sargassum latifolium and S. decurrens are amongst the most characteristic and, during the winter, conspicuous floral species. In particularly clear waters they may be found to depths of up to 8 or 10m. However, profuse growth is usually limited to the top few meters of water. These species usually succumb to the high summer seawater temperatures and by June often the only sign of their presence may be occasional holdfasts. The perennial Hormophysa cuneiformis is a widespread brown alga that is a common exception to the seasonal Sargassaceae die-off. It is found in relative abundance throughout the year, especially across the embayments of the Western Region. It is [only] this group of macroalgae that constitute the ecotype classified in this project.

While the large browns may be the most noticeable and characteristic macroalgae, they are not necessarily present in all ‘algal beds’ and a number of other species contribute to alternate assemblages or form distinct communities. Smaller epilithic brown algae such as Colpomenia sinuosa and Padina spp. may be found on bedrock and as well as being found on algal dominated reefs, rock armouring and channel walls. The coralline red algae Lithophyllum kotschyanum is common in shallow water either forming distinct small nodular branches or as a pink, calcified coating over the substrate (which often includes hermit crab shells!). Other coralline algae such as Jania sp., a small, wiry species, may grow in abundance on exposed rocks, especially in very shallow subtidal water, and are particularly prevalent on the creviced bedrock of the western region. They may also form an understory to the larger brown algae mentioned above. The green fleshy algae Avrainvillea amadelpha is commonly found scattered through many different habitats, but on occasion has, atypically, been observed in large abundances covering the seabed.

Turf algae are a functional rather than taxonomic category and may include species from all three major algae groups. In shallow water, a ‘turf’ of short hairy algae commonly grows in abundance on hard substrates, including coral rubble, concrete and dead reef. They are also pioneer organisms, and often quickly colonise new substrates up to and beyond water depths of 20m, although their domination of such habitats may not be long lived.

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4.4. Fouling community

The biotic assemblage which colonises an artificial habitat (termed fouling community) is determined by numerous factors, primarily (but not limited to): depth, currents, location, materials and length of immersion. While some structures remain largely abiotic, others may support a rich array of species, which includes diverse and abundant coral communities that may be found on older rock armoured breakwaters. Distinct vertical zonation is usually apparent, and sub-tidal fouling communities tend to be especially rich in shallow waters, generally decreasing in diversity and abundance with depth.

The species found in fouling communities are present in the natural hard-bottom or reef habitats that they mirror; however community structure may differ considerably, especially on more recent structures where pioneer species dominate. Fouling communities are usually dominated by sessile suspension feeders such as bivalves (e.g. the Jewel-box clam Chama reflexa), ascidians (both colonial species such as Phallusia nigra and Polycarp sp., and colonial genera including Botryllus and Didemnum), sponges (e.g. Clathrina darwinii, Dysidea chlorea), bryozoans (e.g. Celleporaria pigmentaria), barnacles (Balanus amphitrite) and hydroids (e.g. Pennaria disticha). In turn, these organisms may support a number of associated organisms including brittlestars, polychaete worms, molluscs and crustaceans, with sponges often a harbouring a particularly rich sub-community inside their structure.

Though often dominated by sessile, filter-feeding fauna, initial colonisation of a marine structure usually consists of an algal film, with subsequent floral development often including red algae (e.g. Acanthophora spicifera, or the coralline algae Lithophyllum kotchyanum), green algae (e.g. Cladophora sp.) and / or epilithic brown algae (e.g. Padina spp., Colpomenia sinuosa).

Bibliographical references

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- Emirates Heritage Club - Abu Dhabi. (2004). Marine Atlas of Abu Dhabi (p. 277). Centro Poligrafico Milano SpA. Milan, Italy.
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4.5. Mixed Ecotypes (Habitat Mosaic)

Some marine habitats are particularly heterogeneous and often vary greatly on a scale smaller than the minimum mapping unit (which is $36m^2$ due to the use of RapidEye imagery).

This is particularly true of shallow, near-shore locations where a thin, mobile sediment veneer covers bedrock which vary both spatially and temporally. Often termed a 'Habitat Mosaic', these areas are dynamic and over time sediment may move across the habitat, intermittently covering and exposing the bedrock. Macroalgae may colonise bedrock if exposed, and may even do so through a thin layer of sand. Depending on the stability of the sediment veneer, seagrass may take root (usually low density Halodule uninervis), otherwise either the hard-bottom or unconsolidated sediment substrate is left largely exposed.

The inter-mix of these four habitats and sub-habitats may be patchy and variable and often occurs at a small, even occasionally sub-metre, scale. Mapping such areas is consequently difficult and it must be noted that where a particular habitat is assigned it is quite likely that some or all of the other habitat types account for a proportion of the area.

This is explained further in section 2.1 which describes the principles used for satellite classification. Essentially each pixel has been classified by its dominant habitat type at the time of satellite image acquisition.

5. Characteristics of classification categories

The following information will be provided for each nomenclature category. The subsequent sections describe each category in detail.

Title:

Habitat type code and explicit name of the habitat type

i. Definition – general description of the abiotic features and vegetation and/or anthropogenic description.

ii. Characteristic plant and animal species

iii. Geographical distribution

iv. Habitat types generally associated in the sea

v. Perceived threats

vi. Bibliographical references

vii. This heading includes

viii. This heading excludes

ix. Representative Image of the class

x. Generalisation rules including representative diagrams

5.1. Coral reef container: 11000 (not mapped)

i. Definition

High relief sub-tidal feature formed largely of biogenic rock composed of the remains of scleractinian corals.

This classification is based on geophysical features and does not take account of the current presence or absence of live coral.

ii. Characteristic plant and animal species

Approximately 36 species of hard (scleractinian) coral are present in Abu Dhabi. Corals of the genera Porites (of which three species have been recorded in the Emirate) are the main reef building species, forming the foundation of many of the 'live coral' reefs as well as algal dominated reefs (where the underlying coral colonies have died). Favia, Platygyra and Cyphastrea are also found reasonably frequently, though they are generally not as productive in terms of reef generation. Corals of the genus Acropora (branching corals) were once very widespread across the Emirate and formed monospecific reefs that were particularly dominant in shallow waters (<4m). Although not considered rare, live colonies are now uncommon in comparison.

Section 4.1 discusses corals in the Gulf in more detail.

iii. Geographical distribution

Corals are photosynthetic, and are therefore only present in relatively shallow (sub-tidal) waters where light penetration is better. In Abu Dhabi, scattered colonies may be found in water up to 20m deep; however, reef development is limited to around 12-15m, with the most of the significant reef growth in even shallower water.

iv. Habitat types generally associated in the sea

Acropora-dominated reefs tend to break down relatively quickly due to the branched structure of the corals, producing large quantities of coral rubble. The structure of the reef is reduced in size and complexity, becoming flat with patches of coral rubble.

Where there is no physical relief or where coral rubble exceeds 75%, such areas are classed as a hard bottom habitat remaining structure.

v. Perceived threats

- Climate change: continued elevated seawater temperature events are likely to further reduce the remaining live coral cover
- Coastal development: coastal engineering, land reclamation and dredging
- Industrial development: thermal (and saline) effluents and pollutants from power stations, desalination plants and other industrial activities
- Oil and gas developments. The construction of offshore wells, pipelines and additional infrastructure results in habitat destruction, and there is always a threat of oil spills (though no major incidents have occurred). However, such areas can act as de facto nature reserves by restricting other developments or activities (such as fishing) and in some ways may be beneficial
- Fishing: damage to reefs by fishing gear, destruction of reefs by anchors. Fish populations are impacted directly and through ghost fishing from lost nets and traps (although the latter are now fitted with a biodegradable release 'door' to reduce this issue). Overfishing has also been also shown to disrupt the ecological balance of reef habitats, resulting in increased algal colonisation and a reduced rate of coral recovery
- Coral disease: black band, white band and, less commonly, yellow band diseases have been reported in Abu Dhabi
- Erosion: as the physical structure of 'dead' reefs breaks down, the reef is lost and the amount of substrate suitable for coral recovery is reduced

vi. Bibliographical references

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vii. This heading includes

N/A

viii. This heading excludes

N/A

ix. Representative Image of the class

Please refer to the sub-sections below.

x. Generalisation rules including representative diagrams

Container class for the habitats, not represented on the map.

5.1.1. Fringing Reef: 11100

i. Definition

Linear reef structure close to and parallel to the shoreline

ii. Characteristic plant and animal species

Fringing reefs where live corals are still present may be largely mono-specific, consisting of a single species of Porites, or may support a mixed coral community with the favids Favia, Platygyra and Cyphastrea usually the most frequently recorded genera alongside the three species of Porites. Scattered live colonies of Acropora may be present, though extensive reefs composed mainly of live branching coral colonies are no longer widespread.

Reef-associated species are commonly relatively diverse and include an abundant fish community. Reefs which have suffered widespread coral mortality often still support occasional live corals. Such reefs are usually algal dominated (see section 5.1.2).

iii. Geographical distribution

Fringing reefs follow the coastline of numerous inshore and offshore islands and shoals as well as that of the mainland. Due to greater coastal development towards the eastern side of the Emirate, the remaining fringing reefs tend to be in the Western Region and around the offshore islands.

Prior to 1996, branching corals (Acropora) tended to dominate in shallower waters, while massive corals formed slightly deeper reefs. Although live Acropora reefs are no longer typical, their remains may be found close to the shoreline, often parallel to a deeper band of Porites or mixed massive coral reef slightly further offshore.

iv. Habitat types generally associated in the sea

The sub-habitat 'Fringing reef with macroalgae' is described below

v. Perceived threats

See section 5.1.

vi. Bibliographical references

See section 5.1.

vii. This heading includes

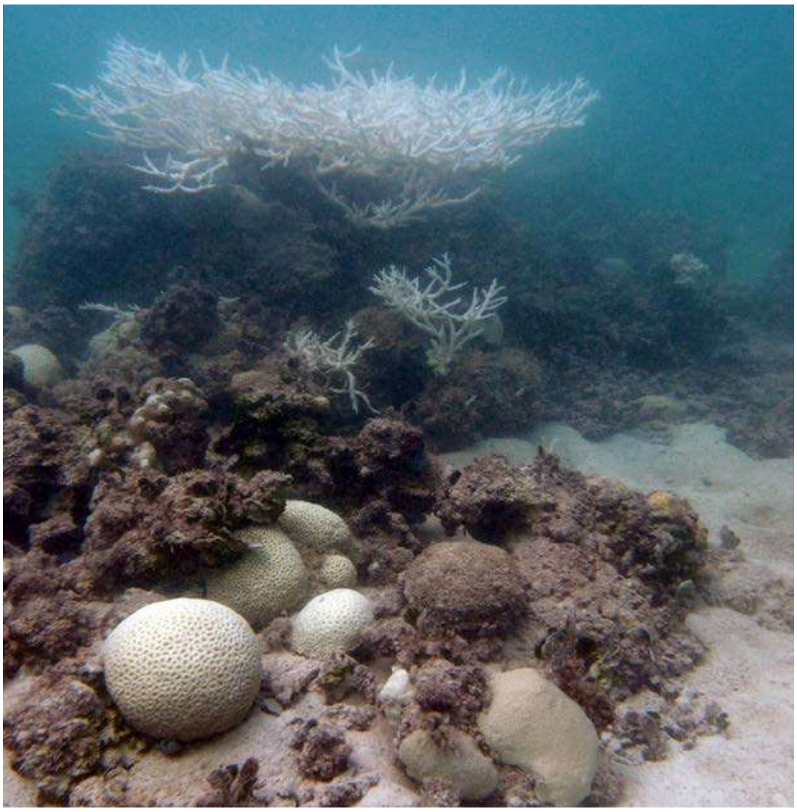
- Reefs where the structure remains but there are no longer live corals.

viii. This heading excludes

- Former reefs where the structure has been eroded flat.

ix. Representative Image(s) of the class

Fringing reef with live *Porites* spp.	
	Depth (m): 6m Location: N24.02991 E52.30968 Date / time of survey 26 Jul 2009 13:19 Characteristic species: *Porites spp*. Ref: N286 – BV66

Fringing reef with mixed coral community.	
	Depth (m): 7m Location: N24.36195 E53.32688 Date / time of survey 28 Aug 2012 13:35 Characteristic taxa: *Acropora spp.* *Cyphastrea spp.* *Favia spp.* *Platygyra spp.* *Porites spp.* N.B. This photograph was taken during the summer when coral bleaching was widespread. Although some of the corals will die, a degree of recovery is likely

x. Generalisation rules including representative diagrams

- Depth limit for classification: 7-8 m of water.
- Classification is based on the shape and spectral features, as well as the positioning related to the coast.
- This class may include small areas of hardbottom or unconsolidated bottom.

5.1.2. Fringing reef with macroalgae: Sub-habitat 11110

i. Definition

Fringing reef structure with greater than 25% macroalgae cover.

This criterion is based on the CMRECS macrohabitat definition for algal bed. It must be noted that it may not be possible to determine the presence of macroalgae when using imagery captured during the summer months due to the seasonal nature of some species.

ii. Characteristic plant and animal species

Sargassaceae; a family of large brown algae, including the seasonal *Sargassum spp.*, *Sirophysalis trinodis* (formerly *Cystoseira trinodis*) and the perennial *Hormophysa cuneiforms*.

A more detailed discussion of macroalgal communities is provided in Section 4.3.

iii. Geographical distribution

This sub-habitat is found only found on fringing reef (please refer to the section above). In particularly clear waters large brown seasonal macroalgae may be found to depths of up to 8 or 10m. However profuse growth is usually limited to the top few meters of water.

iv. Habitat types generally associated in the sea

- Fringing reef

v. Perceived threats

- See Fringing reef section above.

vi. Bibliographical references

- See Fringing reef section above.

vii. This heading includes

viii. This heading excludes

- Fringing reefs with macroalgal communities which do not consist of algae from the Sargassaceae family. For example, fringing reefs covered in turf algae.
- Areas where the algae was not captured in the satellite imagery due to seasonal changes.

ix. Representative Image of the class

Algal dominated fringing reef: Seasonal Sargassaceae	
	Depth (m): 2 to 6m
	Location: N24.36198 E53.34035
	Date / time of survey 28 Feb 2001
	Characteristic species: *Sargassum spp.* *Sirophysalis trinodis* N.B. Macroalgae dies off during the summer
	Ref: N188-74

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10m of water
- Only classified if macroalgae is evident in the satellite image (seasonal species may not be present in imagery captured during the summer months)

5.1.3. Patch Reef: 11200

i. Definition

Isolated, coral outcrop or group of outcrops with no distinct axis relative to the shoreline.

ii. Characteristic plant and animal species

The underlying structure of patch reefs is often formed from Porites spp. Patch reefs support a similar range of plant and animal species to fringing reefs.

iii. Geographical distribution

As corals are photosynthetic, reef growth is limited in depth, with minimal development below 15m.

In comparison to other coral reef systems, patch reefs are usually relatively small, ranging from just a few tens of metres to a few hundred metres across. They are classically found in relatively shallow, flat or gently sloping near-shore areas, and are typically round in shape and surrounded by a halo of sand. More unusual forms include occasional, isolated, steep-sided, domed peaks topped with a sub-surface coral reef structure in deeper waters. Being surrounded by deeper, cooler water than their near-shore counterparts, live coral cover on these 'deeper' reefs is often higher than in shallower areas.

iv. Habitat types generally associated in the sea

The sub-habitat Patch reef with macroalgae is described below.

Patch reefs in shallow water are usually encircled by a ring of unconsolidated sediment, although they may be found adjacent to any of the natural shallow water environments. Where depth allows, there is usually a transition to unconsolidated substrate at around 12-15m.

v. Perceived threats

See section 5.1 above.

vi. Bibliographical references

See section 5.1 above.

vii. This heading includes

- Reefs that no longer support live coral.

viii. This heading excludes

- Reefs where the characteristic 'high relief' structure has been completely eroded.

ix. Representative Image(s) of the class

<table>
<tr><th colspan="2">Patch reef with live Porites spp.</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 6.5m</td></tr>
<tr><td>Location:
N24.49963
E54.33393</td></tr>
<tr><td>Date / time of survey
10 Dec 2008 12:30</td></tr>
<tr><td>Characteristic species:
Porites spp.</td></tr>
<tr><td>Ref: N272 – 12</td></tr>
</table>

<table>
<tr><th colspan="2">Offshore patch reef with live Porites spp.</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 6 – 16m</td></tr>
<tr><td>Location:
N24.09022
E52.15087</td></tr>
<tr><td>Date / time of survey
23 Jul 2009 07:20</td></tr>
<tr><td>Characteristic species:
Porites spp.</td></tr>
<tr><td>Ref: N286-BV71</td></tr>
</table>

x. Generalisation rules including representative diagrams

- Depth limit for classification: 7-8 m of water
- Classification based on shape and spectral features, as well as the positioning related to the coast.
- This class may include small areas of hardbottom or unconsolidated bottom.

5.1.4. Patch reef with macroalgae: Sub-habitat 11,210

i. Definition

Patch reef structure with greater than 25% macroalgae cover.

This criterion is based on the CMRECS macrohabitat definition for algal bed. It must be noted that it may not be possible to determine the presence of macroalgae when using imagery captured during the summer months due to the seasonal nature of some species.

ii. Characteristic plant and animal species

Sargassaceae; a family of large brown algae, including the seasonal *Sargassum spp.*, *Sirophysalis trinodis* (formerly *Cystoseira trinodis*) and the perennial *Hormophysa cuneiforms*.

A more detailed discussion of macroalgal communities is provided in section 4.3.

iii. Geographical distribution

This sub-habitat is found only found on Patch reef.

In particularly clear waters large brown seasonal macroalgae may be found to depths of up to 8 or 10m, however, profuse growth is usually limited to the top few meters of water.

iv. Habitat types generally associated in the sea

Patch reef

v. Perceived threats

See Fringing reef section above.

vi. Bibliographical reference

See Fringing reef section above.

vii. This heading includes

viii. This heading excludes

- Patch reefs with macroalgal communities which do not consist of algae from the Sargassaceae family (for example, fringing reefs covered in turf algae).
- Areas where the algae was not captured in the satellite imagery due to seasonal changes.

ix. Representative Image of the class

Patch reef with Macroalgae	
	Depth (m): 2 to 6m
	Location: N23.97641 E52.16101
	Date / time of survey 22 Jul 2009 14:00
	Characteristic species: Sargassum spp. N.B. Much of the macroalgae has died back due to high summer seawater temperatures
	Ref: N286 - BV64

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10m of water
- Only classified if macroalgae is evident in the satellite image (seasonal species may not be present in imagery captured during the summer months).

5.2. Seagrass Bed: 12000

i. Definition

Sub-tidal habitats with a minimum of 25% cover seagrass.

This classification of is based on the CMRECS macro-habitat criteria for seagrass beds.

ii. Characteristic plant and animal species

The three species of seagrass; *Halodule uninervis*, *Halophila stipulacea* and *Halophila ovalis* (see section 4.2)

Seagrass beds are a critical habitat, playing a vital role in the life cycle of many commercially important fisheries species, as well as being the primary food of the Green Turtles and Dugongs.

iii. Geographical distribution

Seagrass beds are present throughout inshore coastal areas of Abu Dhabi. They may be found from the very low intertidal to a maximum of approximately 15m depth. Sparsely distributed seagrass may be found in deeper waters, though at densities which do not constitute a 'seagrass bed'. They require unconsolidated sediment substrate and are especially prevalent in more sheltered, inshore areas.

iv. Habitat types generally associated in the sea

Seagrasses grow on unconsolidated substrates. Seagrass beds may enclose patches of bare sediment and are often bounded by unconsolidated bottom at both the shallower and deeper end of the habitat.

v. Perceived threats

- Coastal development: coastal engineering, land reclamation and dredging

vi. Bibliographical references

- Al Abdessalaam, T. Z., Das, H., Grandcourt, E., & Rajan, A. (2007). Marine Environment and Resources ofAbu Dhabi. (T. Z. Al Abdessalaam, Ed.) (p. 255). Abu Dhabi: Motivate Publishing.
- Basson, P. W., Burchard, J. E. J., Hardy, J. T., & Price, A. (1977). Biotopes of the Western Arabian Gulf ; marine life and environments of Saudi Arabia (p. 284). Aramco Dept. of Loss Prevention and Environmental Affairs.
- Emirates Heritage Club - Abu Dhabi. (2004). Marine Atlas of Abu Dhabi (p. 277). Centro Poligrafico Milano SpA. Milan, Italy.
- Erftemeijer, P., & Shuail, D. (2012). Seagrass habitats in the Arabian Gulf: distribution, tolerance thresholds and threats. Aquatic Ecosystem Health & Management 15(SI), 73–83
- Green, E., & Short, F. (Eds.). (2003). World atlas of seagrasses (p. 298). University of California Pr.
- Hellyer, P., & Aspinall, S. J. (2005). The Emirates - A Natural History. (p. 428). Trident Press.

- John, D. M., & George, J. D. (2001). The Marine Life of the Emirate of Abu Dhabi. A report for the Abu Dhabi Company for Onshore Oil Operations (p. 166). London.

- Sheppard, C. R. C., Price, A., & Roberts, C. (1992). Marine ecology of the Arabian region: patterns and processes in extreme tropical environments (p. 359). Academic Press.

vii. This heading includes

Mixed habitat areas where seagrass cover is over 25% and is greater than the macro-algal cover.

viii. This heading excludes

Areas where seagrass is present but cover is less than 25% (in line with the CMRECS classification system).

Mixed habitat areas where seagrass cover is greater than 25% but less the macroalgae cover.

Dredged channel beds where seagrass is present.

ix. Representative Image(s) of the class

<table>
<tr><th colspan="2">Seagrass bed: Halodule uninervis dominated</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 5.2m</td></tr>
<tr><td>Location: N24.34053 E53.44975</td></tr>
<tr><td>Date / time of survey 26 Aug 2012 16:45</td></tr>
<tr><td>Characteristic species: Halodule uninervis</td></tr>
<tr><td>Ref: N351-H77</td></tr>
</table>

<table>
<tr><th colspan="2">Mixed seagrass bed</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 8.8m</td></tr>
<tr><td>Location:
N24.03435
E51.81040</td></tr>
<tr><td>Date / time of survey
10 Jul 2009 11:10</td></tr>
<tr><td>Characteristic species:
Halodule uninervis
Halophila stipulacea
Halophila ovalis</td></tr>
<tr><td>Ref: N286 – AV39</td></tr>
</table>

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10m of water.
- Seagrass density has to be greater than 25%.
- Highly depending on the season and the year of image capture.

5.3. Hard-bottom: 13000

i. Definition

Solid substrate without significant live or dead coral colonisation.

A combined total of at least 75% of the seabed must be flat or creviced rock or particulate matter classified as ‘gravel’ or larger on the Wentworth Scale (median grain diameter greater than 4mm). This may include coral rubble, as well as gravel, pebbles, cobbles and boulders.

This criterion is based on the CMRECS macro-habitat definition for hard-bottom.

ii. Characteristic plant and animal species

Sub-tidal rocky shores may support a range of sessile fauna such as sponges, bivalves (e.g. the mussel *Brachidontes variabilis*) and various ascidians. Cracks and crevices in the rock are often particularly well colonised and may provide a refuge for more mobile species like brittlestars and crustaceans. Grazing gastropods (e.g. *Cerithium caeruleum*) are often commonplace, and the underlying bedrock itself may be home to boring species such as the distinctive orange sponge *Cliona sp*. Macroalgae are often present, and are discussed in more detail below (Section 5.3.1).

It is not unusual to find occasional scleractinian (hard) corals, with the hardy, low-growing *Siderastrea savignyana* especially widespread. Non-reef building coral communities may develop, especially in moderately exposed areas shallower than15m depth. Common coral genera include *Porites* and the favids *Favia*, *Platygyra* and *Cyphastrea*.

Areas which are too deep for significant macroalgae growth often support scattered soft corals (Alcyonacea), most commonly the seafans *Rumphella sp.* and *Plexauroides indica* and the seawhip *Junceella sp*. Occasional sponges (Porifera) are virtually ubiquitous and bivalves are particularly common on rocky outcrops (e.g. the hammer oyster *Malvufundus spp.* and the jewel box clam *Chama reflexa*). The pearl oyster *Pinctada radiata* may also be abundant.

This habitat type also includes coral rubble which has become increasingly common following the widespread mortality of branching corals (see Section 4.1).

iii. Geographical distribution

Hard-bottom habitats occur in both shallow, near-shore areas and on the crests of deeper subsea rises, where bedrock is swept clean of sediment.

Hard-bottom areas are generally exposed to greater waves and / or currents than their unconsolidated counterparts, and may be present along unprotected shorelines, between two land masses or in areas shallower than their surroundings. Sub-sea 'peaks' in deeper, offshore areas generally get scoured of sediment, exposing the underlying bedrock, while stable sediment settles in the surrounding lower lying 'valleys'. Similarly, where water movement is great, for example between two shoals or islands, the seabed is largely scoured of sediment and hard-bottom communities develop.

Hard-bottom coral communities are particularly common close to offshore islands, especially in the direction of the prevailing current (often to the northwest), where moderate to high water movement, good water clarity (and therefore light penetration) and a hard substrate combine to make conditions suitable. Although light dependent (and therefore more common in shallower water) these communities have been recorded in depths exceeding 15m.

iv. Habitat types generally associated in the sea

- Macroalgae frequently grow on shallow hard-bottom habitats (sub-habitat 13010).
- Shallow, wave-exposed bedrock may be subject to a thin, mobile veneer of unconsolidated material which intermittently covers and exposes the underlying hard bottom. Such areas may also support seagrass and / or macroalgae (Section 5.3.1.)

v. Perceived threats

vi. Bibliographical references

- Al Abdessalaam, T. Z., Das, H., Grandcourt, E., & Rajan, A. (2007). Marine Environment and Resources ofAbu Dhabi. (T. Z. Al Abdessalaam, Ed.) (p. 255). Abu Dhabi: Motivate Publishing.
- Basson, P. W., Burchard, J. E. J., Hardy, J. T., & Price, A. (1977). Biotopes of the Western Arabian Gulf ; marine life and environments of Saudi Arabia (p. 284). Aramco Dept. of Loss Prevention and Environmental Affairs.
- Emirates Heritage Club - Abu Dhabi. (2004). Marine Atlas of Abu Dhabi (p. 277). Centro Poligrafico Milano SpA. Milan, Italy.
- Hellyer, P., & Aspinall, S. J. (2005). The Emirates - A Natural History. (p. 428). Trident Press.

vii. This heading includes

- Areas where the substrate is composed of particle larger than gravel, for example coral rubble.

viii. This heading excludes

- Hard-bottom areas with a thin sediment veneer
- Coral reef structures, even where no living corals remain
- Hard-bottom areas colonised by macroalgae

ix. Representative Image(s) of the class

Hardbottom with coral community (non reef-building)

Depth (m): 15m

Location:
N24.90249
E53.06820

Date / time of survey
23 Oct 2009 12:26

Characteristic species:
Favia sp.
Platygyra sp.
Cyphastrea sp.
Porites sp.

Ref: N268 – ZR2

Scoured hard-bottom

Depth (m): 14.3m

Location:
N24.97215
E52.68328

Date / time of survey
06 Dec 2010 14:45

Characteristic species:
Rumphella sp.
Plexauroides indica
Junceella sp.

Ref: N335-17

<table>
<tr><th colspan="2">Coral rubble</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 1.5m</td></tr>
<tr><td>Location:
N24.39220
E53.36823</td></tr>
<tr><td>Date / time of survey
28 Aug 2012 11:50</td></tr>
<tr><td>Characteristic species:
Halophila ovalis</td></tr>
<tr><td>Ref: N351-H75</td></tr>
</table>

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10m of water
- Where hardbottom exists with a layer of sediment, classification is unconsolidated bottom.
- Where hardbottom is covered by a dominant (over 25 %) layer of vegetation, classification corresponds to the vegetation (Seagrass, Algal or Sparse Vegetation).

5.3.1. Hard-bottom with macroalgae: sub-class 13,010

i. Definition

Hard-bottom habitats where macroalgae cover is greater than 25%.

This criterion is based on the CMRECS macro-habitat definition for algal bed. It must be noted that classification is based on detection in the satellite imagery analysis, which may have seasonal restrictions.

ii. Characteristic plant and animal species

Sargassaceae; a family of large brown algae, including the seasonal *Sargassum spp.*, *Sirophysalis trinodis* (formerly *Cystoseira trinodis*) and the perennial *Hormophysa cuneiforms*.

A more detailed discussion of macroalgal communities is provided in section 4.3.

iii. Geographical distribution

Hard-bottom with macroalgae habitats are generally found where wave exposure or currents are higher (see Section 4.3) in relatively shallow waters (less than 10m deep), and where light penetration allows adequate photosynthesis. Scattered macroalgae are commonly found in deeper water. However, density is usually too low to term the area an algal bed.

iv. Habitat types generally associated in the sea

Hard-bottom

v. Perceived threats

Coastal development

vi. Bibliographical references

See Section 4.3

vii. This heading includes

- Mixed ecotype 'Habitat mosaic' areas where macroalgal cover is over 25% and is greater than the seagrass cover.

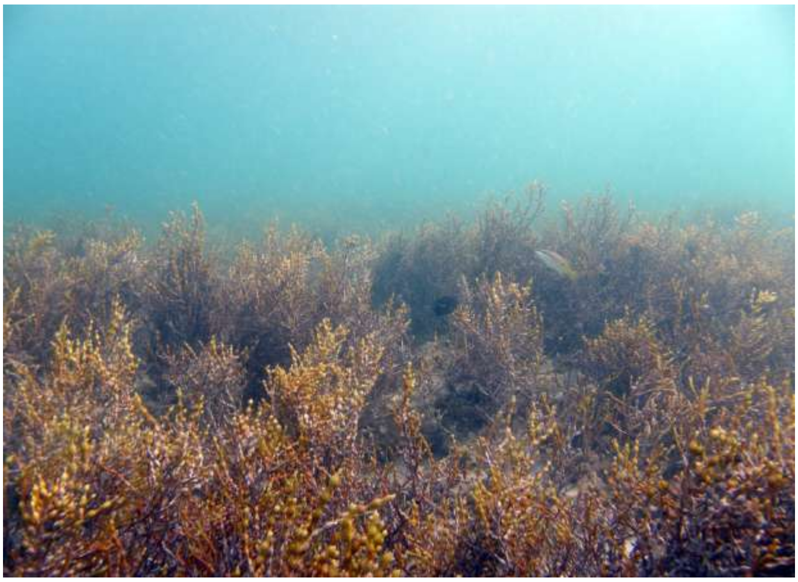
viii. This heading excludes

- Similar algal communities found on coral reefs, rock armouring or other marine structure.
- Algal beds where the algae are not attached to the seabed (e.g. *Chaetomorpha sp.* carpets).

ix. Representative Image(s) of the class

<table>
<tr><th colspan="2">Seasonal macroalgae</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 4.4m</td></tr>
<tr><td>Location:
N23.98055
E52.23155</td></tr>
<tr><td>Date / time of survey
20 Jul 2009 05:56</td></tr>
<tr><td>Characteristic species:
Sargassum spp., Sirophysalis trinodis,

N.B. Macroalgae dies off during the summer</td></tr>
<tr><td>Ref: N286-BM18</td></tr>
</table>

<table>
<tr><th colspan="2">Perennial brown algae (Hormophysa cuneiformis)</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 2.3m</td></tr>
<tr><td>Location:
N23.99330
E52.09212</td></tr>
<tr><td>Date / time of survey
22 Jul 2009 08:05</td></tr>
<tr><td>Characteristic species:
Hormophysa cuneiformis</td></tr>
<tr><td>Ref: N286-BV63</td></tr>
</table>

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10m of water.
- Algal cover greater than 25%
- Only classified if macroalgae is evident in the satellite image (seasonal species may not be present in imagery captured during the summer months).

5.4. Unconsolidated bottom: 14000

i. Definition

Greater than 25% cover of the substrate composed of sediment smaller than 'gravel' on the Wentworth scale (median grain size <2mm), without significant coral, seagrass or algal colonisation.

Based on the CMRECS macro-habitat definition of unconsolidated bottom.

ii. Characteristic plant and animal species

Ranging from course rippled sand in the shallow sub-tidal to much finer stable soft sediment (particularly prevalent in deeper areas). Colonisation is generally lower than in other types of natural habitat.

The instability of mobile rippled sand in shallow water has a very limiting effect on the benthic community; sessile species quickly get smothered and biotic development, sometimes comprising of little more than occasional gastropods (e.g. Nassarius sp. and the dove shell Mitrella blanda), and starfish (e.g. Astropecten monacanthus). With little or no floral or coral development, primary productivity is minimal and overall abundances are commensurately low.

In deeper waters the sediment is usually more stable allowing a slightly richer epibenthic assemblage to develop, although much of the sediment is only covered by a film of microscopic algae on which grazing gastropods such as Strombus persicus feed. Sponges are usually found scattered across the habitat, supporting their own associated community. The characteristic burrows of gobies are also a common feature of the stable sediment

In very sheltered locations, very fine particulate (muds) may settle, creating a still, smothering layer of silt. In such habitats few species survive and even fewer thrive, while those that can, such as the mud snail Clypeomorus bifasciatus may be exceptionally abundant. Development of rooted flora tends to be minimal, although carpets of the filamentous green algae Chaetomorpha sp. may form. Such natural habitats, which are not common, are ecologically comparable to dredged seabeds.

iii. Geographical distribution

Unconsolidated bottoms are the dominant habitat across much of the Emirate, both in shallow and deeper waters. Rippled mobile sand usually forms a narrow band in the very shallow subtidal of exposed shorelines, though is uncommon beyond 3-4m as it grades into a flatter more stable, habitat.

Though uncommon, mud may be found at any depth where the topography largely encloses an area causing a great degree of sedimentation.

iv. Habitat types generally associated in the sea

Unconsolidated bottom can occur alongside all other habitats.

v. Perceived threats

None.

vi. Bibliographical references

- Basson, P. W., Burchard, J. E. J., Hardy, J. T., & Price, A. (1977). Biotopes of the Western Arabian Gulf ; marine life and environments of Saudi Arabia (p. 284). Aramco Dept. of Loss Prevention and Environmental Affairs.
- Hellyer, P., & Aspinall, S. J. (2005). The Emirates - A Natural History. (p. 428). Trident Press.
- John, D. M., & George, J. D. (2001). The Marine Life of the Emirate of Abu Dhabi. A report for the Abu Dhabi Company for Onshore Oil Operations (p. 166). London.
- Sheppard, C. R. C., Price, A., & Roberts, C. (1992). Marine ecology of the Arabian region: patterns and processes in extreme tropical environments (p. 359). Academic Press.

vii. This heading includes

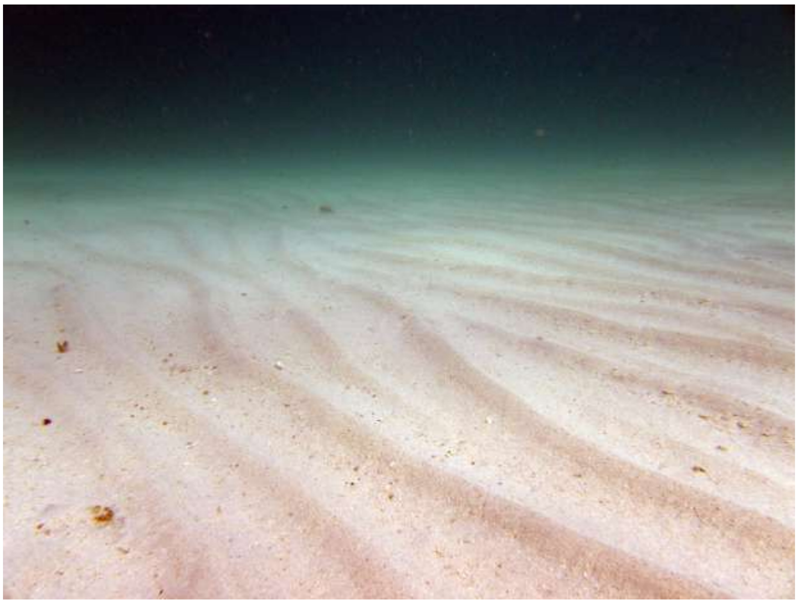
- Areas of dumped dredge spoil where there has been little or no colonisation by macroalgae or seagrass.

viii. This heading excludes

- Dredged area beds.

ix. Representative Image(s) of the class

Rippled mobile sand	
	Depth (m): 4.4m

	Location: N23.98184 E52.23637
	Date / time of survey 20 Jul 2009 08:05
	Characteristic species:
	Ref: N286-BM19 W

Deeper stable soft sediment	
	Depth (m): 17.6m
	Location: N24.07022 E52.24892
	Date / time of survey 24 Jul 2009 10:02
	Characteristic species: Sponges
	Ref: N286 – BV58

x. Generalisation rules including representative diagrams

- Depth limit for classification: 12-15m of water

- Seafloor identified as hard bottom when substrate size is classed as pebble or larger
- Less than 25% [rooted] vegetation

5.5. Marine construction container: 15000 (not mapped)

i. Definition

Artificial structure which is entirely or partially subtidal.

ii. Characteristic plant and animal species

Marine structures are usually colonised by fouling communities. Composition of the community is usually dependant on numerous factors including depth, currents, location, materials and length of immersion. Please refer to section 4.4 for more details.

Marine structures also often act as fish aggregation devices.

iii. Geographical distribution

Largely inshore along the coastline, although oil and gas installations are distributed offshore throughout the emirate.

iv. Habitat types generally associated in the sea

None.

v. Perceived threats

None.

vi. Bibliographical references

Please refer to Section 4.4.

vii. This heading includes

- Sub-tidal sections of reclaimed land
- Marine wreckage and debris

viii. This heading excludes

- Dredged areas
- Areas of dumped spoil dredge which are not becoming reclaimed land.

ix. Representative Image of the class

N/A

x. Generalisation rules including representative diagrams

- Container class for the habitats, not represented on the map.
- Coastal marine structures (e.g. jetties) are overwritten by the terrestrial classification.

5.5.1. Rock armouring / artificial reef: 15100

i. Definition

Modular structure built with un-cemented rock or concrete units.

Rock armouring is usually an angled sea-wall built from either rocks (commonly limestone) or pre-formed concrete units. Their primary function is to provide shelter for either coastal protection (especially of artificial islands) or creation of a harbour. Such structures commonly extend from above the upper intertidal through into the sub-tidal. Artificial reefs are usually sub-surface concrete units deployed specifically as a substrate for colonisation or as a fish aggregation device. Ecologically, they are both functionally similar, although usually deployed at different depths.

ii. Characteristic plant and animal species

Many breakwaters are built in areas that are often quite exposed. By providing a stable, solid substrate in these conditions, rock armoured breakwaters are comparable in many ways to the more natural reefs and hard-bottom habitats of the Gulf. In addition, the limestone rocks commonly used for breakwaters are similar to naturally occurring substrates. As a result rock armoured breakwaters can quickly become well colonised by epilithic species and many support a rich and abundant fouling community. This may include well developed corals, especially on older breakwaters in more exposed locations. However, depending on depth, age, material or environmental conditions, colonisation may be minimal or largely limited to turf algae.

If conditions are suitable, coral cover can be high (50%), but community structure is distinct in comparison to natural reefs and generally fewer species are found. The three most abundant coral genera are the favids Platygyra, Cyphastrea and the boulder coral Porites, although Favia and Siderastrea also reasonably widespread. The structure of breakwaters and artificial reefs provides both food and shelter for a host of fish species including; snappers (*Lutjanus spp.*), Hammour (*Epinephelus coioides*), Rabbitfish, goatfish, angelfish and bream.

iii. Geographical distribution

Rock armouring is largely (although not exclusively) coastal, while scattered artificial reefs have been deployed throughout the Emirate in a variety of depths and locations.

iv. Habitat types generally associated in the sea

N/A

v. Perceived threats

N/A

vi. Bibliographical references

In addition to the references listed in section 4.4:

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vii. This heading includes

viii. This heading excludes

- Vertical concrete seawalls.

ix. Representative Image(s) of the class

Rock armouring with mixed coral community	
	Depth (m): 7m
	Location: N24.48306 E54.33028
	Date / time of survey 21 Jan 2009 16:30
	Characteristic species: Favid and poritid species *Siderastrea savignyana*
	Ref: N272-30

Fouling community on rock armouring	
	Depth (m): 3m
	Location: N24.50192 E54.36036
	Date / time of survey 22 Jan 2009 15:20
	Characteristic species:
	Ref: N272 - 25

Bare rock armouring

	Depth (m): 2m
	Location: N24.87351 E53.09134
	Date / time of survey 26 Oct 2009 16:30
	Characteristic species:
	Ref: N268 – ZR40

Turf algae on rock armouring	
	Depth (m): 0.5m
	Location: N24.48988 E54.33011
	Date / time of survey 11 June 2009 12:15
	Characteristic species: Turf algae *Echinometra mathaei*
	Ref: N272-11

x. Generalisation rules including representative diagrams

- Only in WV2 images
- Depth limit for classification: 2-3m of water

5.5.2. Marine structure: 15200

i. Definition

Man-made structures (other than rock armouring / artificial reefs) including jetties, oil platforms, bridges, and aquaculture infrastructure.

ii. Characteristic plant and animal species

Due to the diversity of this class there are likely to be many exceptions to any generalisations about species and communities. Structures may range from being abiotic through the specific species farmed in aquaculture ventures, to being diverse within the fouling communities, detailed in 4.3 and 5.5.

Many man-made structures, especially when located offshore, act as fish aggregating devices, attracting an abundant fish community.

iii. Geographical distribution

Coastal developments such as bridges, jetties and channel markers are very common, in near-shore areas. In Abu Dhabi waters, many offshore structures are associated with the oil and gas industry.

iv. Habitat types generally associated in the sea

N/A

v. Perceived threats

N/A

vi. Bibliographical references

See section 4.3.

vii. This heading includes

- Aquaculture infrastructure
- Marine wreckage

viii. This heading excludes

- Rock armouring / artificial reefs
- Dredge spoil dumps

ix. Representative Image of the class

Fouling community on marine structure

	Depth (m): 0-15m
	Location: N24.69406 E52.56839
	Date / time of survey 12 Nov 2009 10:30
	Characteristic species: Fouling community
	Ref: N268 - AR25

x. Generalisation rules including representative diagrams

- Coastal marine structures which are not subtidal are overwritten by the terrestrial classification

5.6. Dredged areas: 16000 (not mapped)

i. Definition

Areas where the water depth has been significantly increased by artificial means, usually either for navigation purposes (generally channels) or for generation of aggregate material (borrow pit).

Dredged areas usually consist of a flat or gently sloping, unconsolidated seabed (‘Dredged Seabed’, Habitat 16,100) bounded by steeply sloping or vertical sides (Dredged edge, Habitat 16,200). The transition from one to the other may or may not be distinct.

The CMRECS ‘relief’ modifier (which defines ‘gently sloping’ as less than 35° and steeply sloping as greater than 35°) has been used to define and distinguish the two habitats.

ii. Characteristic plant and animal species

Dredged areas vary greatly in size, depth and shape, depending on their purpose and location. Some of the smaller navigation channels are just a few meters wide and less than 3m deep, while sections of the Mussafah Channel are over 800m wide and 11m deep. While channels are usually linear, facilities such as ports and harbours (which are commonly dredged for navigation purposes) are a variety of shapes and depths. Borrow pits come in a greater variety of shapes and often have haphazard, meandering boundaries, especially when they are not constrained by other developments in the area.

Typically, dredging produces a deep, flat area of seabed bordered by a steep sided slope up to the original depth. Although unequivocally linked, these two components support very different assemblages; dredged seabeds are often very low in diversity, while dredged walls usually support a richer fouling community.

Along with the extraction of material, dredging also removes all epibenthos, thereby destroying any existing community. The artificial environment created as a result is deeper and usually drastically different to the original. Recovery to a state similar to the original habitat is extremely unlikely and these modified conditions are usually not conducive to significant recolonisation. This is especially true of the bottom of dredged seabeds, which include many of the least diverse, and most impacted marine areas in the Emirate. Although occasionally supporting seagrass, this habitat is usually of very low ecological value.

Although not a particularly ecologically valuable habitat when initially created, dredged walls commonly support a much more species rich fouling community than the adjacent dredged seabed. The fouling community may develop to include some coral colonisation as well as often supporting a moderately abundant fish assemblage.

A more detailed description of the species found in each habitat is included in the respective sections below.

iii. Geographical distribution

Dredged areas are largely found inshore coastal developments, although are also present offshore, especially in association with oil and gas developments.

iv. Habitat types generally associated in the sea

N/A

v. Perceived threats

N/A

vi. Bibliographical references

- Emirates Heritage Club - Abu Dhabi. (2004). Marine Atlas of Abu Dhabi (p. 277). Centro Poligrafico Milano SpA. Milan, Italy.

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vii. This heading includes

viii. This heading excludes

- Spoil dump grounds.

ix. Representative Image of the class

N/A

x. Generalisation rules including representative diagrams

- Container class for the habitats, not represented on the map.

5.6.1. Dredged Seabed: 16100

i. Definition

Dredged areas where the seabed gradient is 'flat' or 'gently sloping' (less than 35°).

The slope criteria is based on the CMRECS relief modifier.

ii. Characteristic plant and animal species

Dredged seabeds are flat or gently sloping and usually unconsolidated. There is often reduced circulation creating a low energy environment where sedimentation of fine particulate matter smothers the seabed and creates a thick layer of easily-disturbed fine silt. Such areas may also be prone to stratification, leading to hypoxic conditions. Occasionally afaunal, benthic diversity is minimal, often consisting of just mud snails (*Clypeomorus bifasciatus*), peanut worms (*Sipunculids*) occupying old gastropod shells, worm casts and occasionally a carpet of filamentous algae.

Where conditions are less severe, a slightly less depauperate community may develop, which can include seagrass (usually sparse *Halophila ovalis*, see Section 4.2). Occasionally, where water movement is substantial, dredged channels may have a hard-bottom substrate, in which case they may support sponges, ascidians, bivalves and other predominantly filter feeding organisms. Overall however, dredged seabeds tend to have very low diversity.

iii. Geographical distribution

See section 5.6.

iv. Habitat types generally associated in the sea

Dredged seabeds are usually, though not exclusively bounded by dredged walls. Areas within coastal developments such as ports and harbours are commonly bordered by rock armouring or other marine structures.

v. Perceived threats

N/A

vi. Bibliographical references

Refer to section 5.6.

vii. This heading includes

N/A

viii. This heading excludes

N/A

ix. Representative Image of the class

Dredged Seabed	
	Depth (m): 13m
	Location: N24.48797 E54.34653
	Date / time of survey 22 Jan 2009 13:00
	Characteristic species:
	Ref: N272-34 W

x. Generalisation rules including representative diagrams

- Depth limit for classification: 10-12m of water
- Seabed is often not visible in the imagery

5.6.2. Dredged Edge: 16200

i. Definition

Linear feature along boundary of a dredged area where the seabed gradient is ‘steeply sloping’ (greater than 35°).

The slope criterion is based on the CMRECS relief modifier.

ii. Characteristic plant and animal species

Dredged area walls vary greatly in terms of substrate, slope, depth, currents and age. All of these factors significantly alter the biotic assemblages to be found. Therefore only a generalised description can be provided.

As opposed to the dredged seabeds which are usually quickly covered by a layer of unconsolidated particulate matter, the steeper inclines and stronger currents often found at the edge of dredged areas tend to reduce sedimentation, leaving the underlying substrate of dredged walls largely exposed. Where this is rock, the remaining substrate typically has variable physical relief ranging from stepped rock with overhangs and crevices, to vertical rock faces. Where the original substrate is unconsolidated, the slope will be reduced, instability increased and sedimentation likely to be greater, and with it usually a reduced level of colonisation. In some coastal developments, dredged areas are may be edged by a vertical concrete wall.

Fouling communities typically develop (see Section 4.2), which may include occasional corals (e.g. *Siderastrea savignyana*, *Favia spp.*) if conditions are suitable. Most dredged walls show significant vertical gradients. Shallower areas tend to support a greater diversity and abundance of species as currents and light penetration tend to be greater. Deeper, stiller waters have more sedimentation, less light and reduced food supplies for filter feeding organisms, resulting in fewer species. This gradient may continue across the transition into the usually depauparate Dredged Seabed habitat.

Overhangs and high relief found in many dredged walls provide a more structurally complex habitat in and over which a moderate diversity and reasonable abundance of fish may be found. Actual community composition and abundance depends greatly on the water quality as well as the physical structure at that site, but species commonly include snappers (*Lutjanus sp.*), sweetlips (e.g. *Plectorhinchus sordidus* - known locally as 'Yanam'), Yellowbar Angelfish (*Pomacanthus maculosus* or 'Anfooz') and even Hammour (*Epinephelus coioides*).

iii. Geographical distribution

See section 5.6.

iv. Habitat types generally associated in the sea

Dredged edges are only found around dredged seabed areas

v. Perceived threats

N/A

vi. Bibliographical references

See section 5.6.

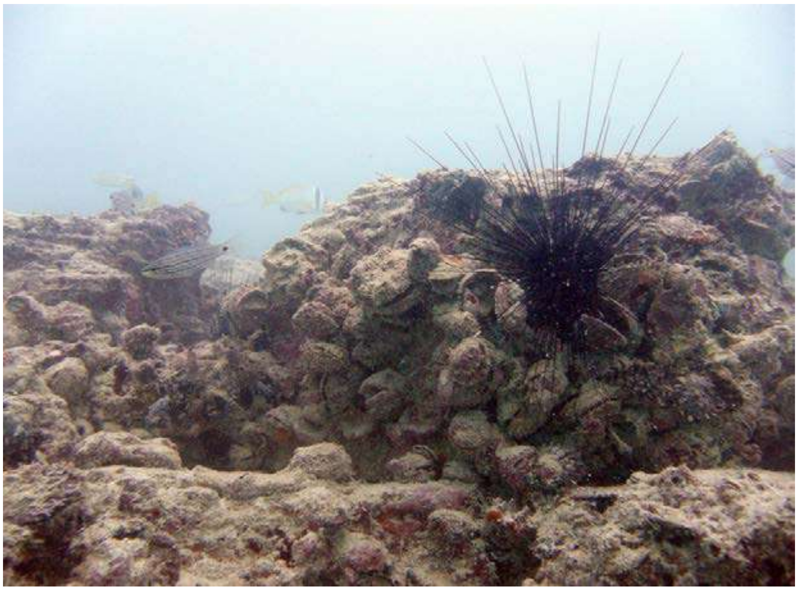
vii. This heading includes

Concrete walls bounding dredged areas

viii. This heading excludes

Rock armouring adjacent to dredged areas

ix. Representative Image of the class

Dredged wall	
	Depth (m): 6m
	Location: N24.49387 E54.32709
	Date / time of survey 10 Dec 2008 13:15
	Characteristic species: Fouling community
	Ref: N272-2 W

x. Generalisation rules including representative diagrams

- Classified as a linear feature around dredged areas

5.7. Deep sub-tidal seabed: 17000

i. Definition

Seabed areas beyond the depth to which satellite imagery can distinguish habitat type.

ii. Characteristic plant and animal species

The habitat is comprised of two fundamental components; unconsolidated and hard-bottom. Unconsolidated sediments dominate, and a layer of stable soft sediment covers the majority of the seabed, but sub-sea 'peaks' that rise above the surrounding seabed generally get scoured of sediment, exposing the underlying bedrock.

Both unconsolidated and hard-bottom communities are a continuation of their shallower counterparts (sections 5.3 and 5.4, respectively). Colonisation is often sparse. Occasional corals or plants may be present, but such areas are generally too deep for significant development of photosynthetic organisms because of light attenuation through the water column.

Unconsolidated substrates may be covered by a film of microscopic algae on which grazing gastropods such as *Strombus persicus* feed. Sponges are usually found scattered across the habitat, supporting their own associated community. The characteristic burrows of gobies are also a common feature. The seafans *Rumphella sp.* and *Plexauroides indica* are frequently scattered across hard-bottoms areas. Occasional sponges (Porifera) are usually present and bivalves are particularly common on rocky outcrops.

Marine constructions may be present. Structures which are super-tidal are overwritten by the terrestrial classification, and at this depth wholly sub-tidal structures are generally limited to pipelines, shipwrecks and very occasional artificial reefs, all of which have quite a limited extent.

Occasionally borrow pits have been dredged, especially around oil and gas installations although, again, they account for only a fraction of the area.

iii. Geographical distribution

Deeper areas tend to occur offshore.

iv. Habitat types generally associated in the sea

The habitat grades into the shallower (mapped) unconsolidated bottom (Section 5.3) and hard-bottom (Section 5.4) habitats.

v. Perceived threats

N/A

vi. Bibliographical references

Please refer to the relevant unconsolidated and hard-bottom sections (sections 5.3 and 5.4 respectively)

vii. This heading includes

Any area too deep to be mapped using satellite imagery.

viii. This heading excludes

N/A

ix. Representative Image(s) of the class

Deep Hard-bottom	
	Depth (m): 14m
	Location: N24.97215 E52.68328
	Date / time of survey 06 Dec 2010 14:45
	Characteristic species: *Rumphella sp.*
	Ref: N335-17

<table>
<tr><th colspan="2">Deep unconsolidated sediment</th></tr>
<tr><td rowspan="5"></td><td>Depth (m): 6m</td></tr>
<tr><td>Location:
N25.00138
E52.70940</td></tr>
<tr><td>Date / time of survey
06 Dec 2010 10:10</td></tr>
<tr><td>Characteristic species:
Sparse</td></tr>
<tr><td>Ref: N335-15</td></tr>
</table>

x. *Generalisation rules including representative diagrams*

- Includes all areas too deep for classification

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- Al Abdessalaam, T. Z., Das, H., Grandcourt, E., & Rajan, A. (2007). Marine Environment and Resources ofAbu Dhabi. (T. Z. Al Abdessalaam, Ed.) (p. 255). Abu Dhabi: Motivate Publishing.

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